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Date: 08/08/02
Time: 18:56:53

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FSG

ELECTRON BEAM TREATMENT OF FLUORINATED SILICATE GLASS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention pertains to dielectric films, more particularly the invention pertains to stabilized fluorosilicate glass films which are useful for the production of microelectronic devices.

2. Description Of The Related Art

The semiconductor industry is rapidly decreasing the dimensions and increasing the density of circuitry and electronic components in silicon chips and integrated circuits. In addition, integrated circuits are being layered or stacked with ever decreasing insulating layer thickness between each circuitry layer.

In the production of advanced integrated circuits that have minimum feature sizes of 0.25 micrometers and below, problems of interconnect RC delay, power consumption and crosstalk become significant. With these decreasing geometries and device sizes, the semiconductor industry has sought to avoid parasitic capacitance and crosstalk noise caused by inadequate insulating layers in the integrated circuits. One way to achieve the desired low RC delay constants involves use of dielectric material in insulating layers that have a low dielectric constant. The use of low dielectric constant (K) materials for interlevel dielectric and intermetal dielectric applications partially mitigate these problems. However, the material candidates which are used by the industry, having dielectric constants significantly lower than the currently employed dense silica, suffer from disadvantages. Most low dielectric constant materials developments use spin-on-glasses and fluorinated plasma chemical vapor deposition SiO_2 with K of greater than 3.

Silicon dioxide is frequently used as an insulator or as a gate material on silicon-based integrated circuits. Typical applications of thin silicon dioxide films include protective coatings, gate insulators for field effect transistors, passivation or inter-metal layers for elemental and compound semiconductor devices, and capacitor dielectrics for memory devices. A film that is commonly used for this purpose is fluorinated silicon oxide. Incorporation of fluorine into the SiO lattice reduces its dielectric constant due to fluorine's high electronegativity and low polarizability. Incorporation of fluorine into silicon dioxide can also reduce radiation-induced oxide charges, and improve the hot-electron immunity of the dielectric. Previous approaches to depositing fluorinated silicon oxide films have included plasma enhanced chemical vapor deposition, electron cyclotron resonance plasma chemical vapor deposition, and atmospheric pressure chemical vapor deposition using Si precursors such as SiF_4. The incorporation of fluorine maintains the physical properties of the films, while improving their electrical properties, such as reducing failures due to early dielectric breakdowns, enhancing performance as an insulator, and reducing the presence of unwanted electrical charges within the silicon dioxide lattice. The formation of fluorinated silicate glass (FSG) dielectric layers for use in microelectronic devices is known from U.S. Pat. Nos. 5,492,736; 5,643,640; 5,660,895; 5,807,785; 5,876,798; 5,888,905 and 5,939,831 which are incorporated herein by reference.

The difficulty of integrating FSG into semiconductor devices is due to the instability of the fluorine in the silicon dioxide film. The fluorine is added to the film to lower the dielectric constant and the amount of fluorine is limited by the stability of the fluorine in the film. If the fluorine is not stable in the film it can produce several detrimental results. These include migration to active areas of the device, corrosion of the metal or other materials in the device, and degradation of the dielectric constant. Successful implementation of FSG has been limited due to the technical challenges of maintaining a stable film with a low dielectric constant.

By incorporating fluorine into the SiO_2 film a dielectric constant in the range of 3.0 to 3.5 can be achieved depending on the amount of fluorine in the film. Being able to use fluorinated SiO_2 is advantageous because existing oxide CVD processes can be extended to future device generations that require a dielectric constant of less than that of standard oxide which is 3.8 to 4.2. This would provide a cost advantage to device manufacturers because they can extend their existing oxide CVD equipment with minimal cost.

There has been some process development using plasma treatments of the FSG films to try and stabilize the fluorine in the film. These processes have the drawback that they are surface treatments and cannot affect changes in the bulk of the FSG film. Plasma processing has not had a significant impact on the amount of fluorine that can be included to provide a lower dielectric constant. Thus, this type of processing has only been marginally accepted. There is a continued desire to provide a more stable low dielectric constant FSG film that is a production worthy process. U.S. Pat. No. 5,946,601 shows a method for decreasing fluorine outdiffusion by depositing a fluorine barrier layer between a metal layer and a low k material. The fluorine barrier layer is amorphous hydrogenated carbon nitride or amorphous carbon nitride.

The present invention applies an electron beam treatment to the FSG film to stabilize the fluorine in the oxide structure of the film. Because the electrons can penetrate the entire thickness of the FSG film, they can modify the properties of the FSG film through the bulk of the film. The electron beam reduces the moisture in oxide films as well as reduces the hydrogen level in oxide films. This reduces the potential for the fluorine to interact with moisture or hydrogen and form HF acid which contributes to the corrosion of the metals and other materials in the device structure. The electron beam also densifies oxide films which leads to a more stable film. The electron beam may allow for some amount of the fluorine to leave the film, eliminating excess fluorine, and this would provide a more stable FSG film as these fluorine atoms would no longer be able to move or react within the FSG film.

SUMMARY OF THE INVENTION

The invention provides a process for producing a fluorinated silicate film which comprises depositing a fluorinated silicate film onto a substrate and then exposing the fluorinated silicate film to electron beam radiation.

The invention also provides a process for stabilizing fluorinated silicate film which comprises exposing a fluorinated silicate film to electron beam radiation under conditions sufficient to stabilize the fluorinated silicate film compared to the fluorinated silicate film prior to such exposure.

The invention further provides a microelectronic device which comprises a substrate, and a fluorinated silicate film on the substrate, which fluorinated silicate film has been exposed to electron beam radiation under conditions sufficient to stabilize the fluorinated silicate film compared to the fluorinated silicate film prior to such exposure.

The invention still further provides a process for producing a microelectronic device which comprises: